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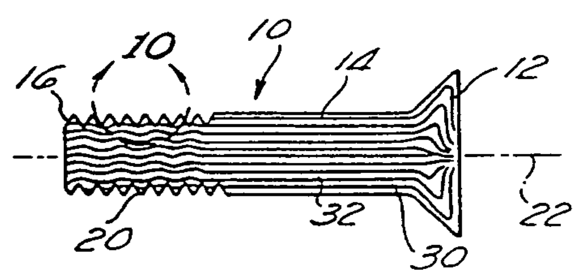

(57) Abstract

Disclosed is a fastener made of composite material having a head portion (12), a tail portion (16) and a cylindrical shank (14) interposed therebetween. While the fibers (30) in the head and tail portions have been deformed from their initial straight orientation during the forming process, the fibers in the shank section remain straight to improve the shear strength of the fastener. The fastener (10) is formed by warm upsetting the threads and head while keeping the shank relatively cool, well below the melting point of the composite binder. The fastener may be formed by a device having a head die (102), a thread die (120), means for selectively heating the tail and head ends of the blank before applying compression thereto, and means for keeping the shank below the temperature at which it will deform.

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IMPROVED COMPOSITE FASTENER AND METHOD AND APPARATUS FOR MAKING SAME

Field of the Invention

This invention relates to composite fasteners such as those threaded fasteners useful in aircraft construction, and the methods and apparatus for making such fasteners.

Background of the Invention

During the past 25 years, many hundreds of millions of metal threaded shear pins have been used in the construction of both civilian aircraft and military aircraft. These fasteners are very similar in appearance to the commercial bolts which have been available for many years for fastening together all kinds of structures. However, shear pins differ from the more widely used bolts in that they are designed for use in joints wherein the major load is a shear load, and wherein the tension loads are relatively low. For these reasons, and because light weight is of great importance in aircraft construction, the manufactured head on a shear pin is usually made smaller and lighter than the manufactured head on a commercial bolt. Similarly, the nuts used on such shear pins are usually smaller and made from a lighter material than the pin itself. For instance, commonly used shear pins have steel or titanium bodies to provide high shear strength, while the nut used is typically made of aluminum.

A composite material is a physical combination of two or more materials, both of which are usually visible to the naked eye. A very early example is the use of straw, in biblical times, to reinforce mud bricks for building. More recent examples are the use of steel bars to reinforce concrete, the use of glass fiber to reinforce polyester resin in the making of boats, and the use of carbon fiber to reinforce various polymeric resins for aircraft construction.

The use of composite materials of the resin plus fiber reinforced variety in military fighter aircraft has increased very rapidly in the last 20 years. For instance, in the F14, which is a twenty-year old design, 0.8% of the total structural weight of the aircraft is made from composite materials. In the F15, 1.6% is composite; in the F16, 2.5% is composite; in the F18, 9.5% is composite; and in the ATF, which is now being designed, 50% of the aircraft structural weight is expected to be composite. In large transport aircraft in 1985, 3% of the aircraft's structural weight was composite and, by 1995, this percentage is expected to increase to 65% according to one forecast.

It had been hoped that these composite structures could be held together by adhesives alone, but this has not been found practical. In conventional aluminum aircraft, approximately twenty-five fasteners per square foot of external surface area are used. In composite aircraft, it is still necessary to use approximately twelve fasteners per square foot of outside surface area.

Up to the present time, specially-shaped and modified metal fasteners have been used in composite structures. These fasteners have been reasonably satisfactory, but they are now seen as being, in many cases, unnecessarily strong, unnecessarily heavy and, unnecessarily expensive. Thus, a need exists for nonmetallic fasteners which are sufficiently strong, but lighter and less expensive than metal. The aircraft threaded shear pins and nuts previously mentioned are examples of a type of aircraft fastener which would be particularly desirable if available in a strong nonmetallic material.

Plastic materials have been used for nuts and bolts, but the unreinforced materials that have commonly been used for these fasteners in the past have not been strong enough for use as aircraft fasteners. Typically, such non-aircraft fasteners have possessed shear strengths of around 5-10 ksi. Recently, injection-molded short fiber

reinforced fasteners have been produced having shear strengths in the range of 9-18 ksi. These are satisfactory for aircraft use in some applications. Also, compression-molded fasteners reinforced with short glass or carbon filament fibers have been produced with shear strengths in the range of 13-40 ksi, and these may find some use in aircraft. However, at the present time shear pins made from these compression molded materials have been found to exhibit insufficient consistency in shear and tension properties for wide aircraft use.

Use of increasing quantities of composite material to fabricate aircraft results in weight savings and other advantages. Weight savings, of course, make it possible to either carry a greater payload over a given distance, or to travel a greater distance with the same payload.

The use of composite fasteners offers weight savings as well as additional advantages. For example, use of a composite fastener in a composite structure means that a fastener may often be chosen which has a coefficient of expansion equal to that of the surrounding structure. Similarly, a composite material can be chosen for a composite fastener such that the fastener does not heat up or otherwise interfere with electromagnetic functions in the vicinity of electronic devices such as radar transmitters. In military aircraft which are often designed to achieve low radar visibility, use of composite fasteners in place of metal fasteners helps to reduce such visibility. Notwithstanding the suitability of composite fasteners for use in aircraft, their attractiveness would be enhanced in that application by an increase in shear strength, which allows use of fewer fasteners per pound of load to be supported.

Accordingly, a need exists for improved, composite fasteners having improved shear strength and a method and apparatus to make the same.

Summary of the Invention

The fasteners of the present invention are made from composite material having a plurality of long fibers bonded together by a binder. These warm formed fasteners have three portions: a cylindrical shank portion to carry bearing and shear loads; a head end integral with the shank; and a threaded tail end integral with the shank opposite the head. The fibers within the head and tail portions of the fastener are not straight, having been deformed during the warm forming operation. By way of contrast, the fibers in the shank portion are straight. The undeformed fibers of the shank portion provide the shear strength in the fastener. Fasteners recently made in accordance with the present invention have average shear strengths in the vicinity of 50 ksi. Also, cylindrical blanks have been fabricated with a shear strength in excess of 60 ksi, therefore it follows that fabricated shear pins in the vicinity of 60 ksi should be available in the near future.

The fasteners of the present invention are made from a composite blank in a die having a thread forming cavity and a head forming cavity and means for selectively heating the blank portions within those cavities. The fastener is made by selectively heating the blank end adjacent the thread forming cavity to a temperature sufficient to permit the material to deform while maintaining the blank shank portion below that temperature, compressing the blank so as to force the blank thread end material to deform into the thread forming cavity, thereby forming a fastener thread on the blank tail end, selectively heating the blank adjacent the thread forming cavity to a temperature sufficient to permit deformation of the material while maintaining the blank shank portion below that temperature, and compressing the blank so as to deform the blank head end material into the head forming cavity to form threads on the head end.

Brief Description of the Drawings

Figure 1 is a perspective view of a stack of composite tape plies formed into a panel, showing a typically square composite bar separated therefrom.

Figure 2 is a detailed perspective view of a corner of the sheet shown in Figure 1.

Figure 3 is an enlarged perspective view of a composite rod machined from the composite bar shown in Figure 1.

Figure 4a is a perspective view of a composite bar cut from the bar of Figure 1.

Figure 4b is a perspective view of a fastener blank machined from the bar of Figure 4a or the rod of Figure 3.

Figure 4c is a perspective view of a threaded blank formed from the blank of Figure 4b.

Figure 4d is a perspective view of a fully-headed fastener.

Figure 5 is a cross-sectional view of a composite fastener constructed in accordance with the prior art warm forming process.

Figure 6 is a cross-sectional view of a composite fastener constructed in accordance with the present invention.

Figure 7 is a cross-sectional view of a fastener blank in the apparatus of the present invention.

Figure 8 is a cross-sectional view of a threaded blank shown in the apparatus of Figure 7.

Figure 9 is a cross-sectional view of a fully-headed fastener shown in the apparatus of Figure 7.

Figure 10 is an enlarged view of the thread portion of the fastener of Figure 6 illustrating the fiber orientation.

Figure 11 is an enlarged view of the head portion of the fastener of Figure 6 illustrating a typical fiber orientation.

Figure 12 is a bar chart illustrating characteristics of prior fasteners.

Figure 13 is a bar chart illustrating characteristics of the fasteners of the present invention.

Detailed Description of the Preferred Embodiment

Referring to Figures 1 and 4a - 4d, the fastener 6 of the present invention is formed from a composite material. That composite material is initially formed in thin sheet-like tapes, called plies, containing fibers which add to the strength of the plies. A suitable tape has a thickness of about .005 inch, but other thicknesses can be utilized. Each tape contains a plurality of individual carbon or orther reinforcing fibers which are twisted or otherwise held together in a bundle referred to as a tow. A commonly used fiber is about 7 microns in diameter. A commonly used tow contains 12,000 individual fibers. The tows are arranged parallel to each other and are bonded together using a binder of polymeric resin. A common binder for binding the carbon fibers and tows together is the thermoplastic polymer polyetheretherketone (PEEK). As will be appreciated from Figure 3, the tows, each composed of individual filaments, are generally parallel to each other and greatly increase the shear strength of the tape in the direction perpendicular to the fibers. These tows also greatly increase the tension strength in the direction of the fiber flow, but it is the shear strength that is of primary interest in this invention.

The tapes can be made into panels 36 such as shown in Figure 1. To make a panel, a number of plies 34 of tape, commonly .005 inch in thickness each, are stacked one on top of the other, as more clearly seen in Figure 2. The stack is then heated while applying a compressive load. This process causes the binder in adjacent plies of tape to bind the plies together. After the panel 36 is formed, it is cooled. This creates a rigid composite panel 36 having the desirable characteristics discussed above.

The physical characteristics of the resulting fastener may be affected by the orientation of the plies, that is the direction of the fibers in the adjacent plies.

Orientation of the fibers in the same direction is called a "unidirectional" layup. If a first layer is oriented along the longitudinal axis of the panel, a second layer oriented at -45° from said axis, a third layer oriented at +45° from said axis and a fourth layer is oriented at 90° to said axis, the panel is said to have a "0/+45/-45/90" or "quasi-isotropic" layup. Layup angles and the order in which each layer is stacked, are chosen in order to produce the desired combination of properties in the part being manufactured.

To use the material to make a fastener, a section or bar 40 is cut from the edge of the panel, as indicated in Figure 1. The bar 40 can then be machined by turning it on a lathe or by grinding between centers and cut into shorter pieces to produce a cylindrical rod 50 as shown in Figure 3. As an alternative, the bar 40 may be simply cut into individual shorter pieces of bar stock 42.

Figures 4a - 4d show the manufacture of an individual fastener in stages. The square cross-section bar stock 42 or cylindrical rod 50 are turned on a lathe or are ground to produce blanks 52 as shown in Figure 4b. The portion of the blank 52 to be formed into threads is cut down to a diameter approximately .005 inch smaller than the minor diameter of the thread to be formed. The resulting blank 52 is shown in Figure 4b. That blank 52 has a head end 54, shank portion 56 and tail end 58.

The machined blank 52 is then inserted into a suitable die. In the prior art, the die and the blank 52 were heated to slightly above the melting point of the binder and pressure was applied to the blank 52 in a single step from the head end of the blank. By way of example, the melting point of a commonly-used binder, PEEK, is approximately 650°F. The prior art contemplates heating the entire blank to approximately 725°F. Application of pressure caused the blank tail end 58 to form into threads 20 at the fastener tail 16 and caused the blank head end 54 to be formed into the large end of the die to form the head 12. The fastener

10 was then allowed to cool to about 400°F or lower and removed from the die. Any excess material was machined from the top of the head to achieve the required head height.

This process has been described as "warm upsetting," which distinguishes it from cold forming processes such as machining and other warm forming processes such as injection or compression molding which have been used to produce fasteners having average shear strengths in the range of 13-40 ksi.

The prior art method above described used to produce fasteners typically having average shear strengths in the range of 30-49 ksi. However, analysis of shear test results indicated that the shear average strength of the shank of these prior art fasteners was approximately 1 to 18 ksi less than the average shear strength value of the rods 50 which were cut and machined from the original panels. The reason for this is not completely understood. However, comparison of the microstructures of the fastener shank with that of the original rods revealed that the decrease in shear strength of the fastener over the rods was associated with a less uniform distribution of fibers throughout the cross-section of the fastener shank taken at right angles to the fastener longitudinal axis, some binder-rich areas distributed throughout the cross-section, and fiber deformation. The fiber deformation resulted in deviations from straightness in the fibers so that the fibers assumed a wavy configuration, as shown in Figure 5. By way of contrast, the rods 50 showed uniform cross-sectional distribution of fibers, no significant binder-rich areas, and generally straight fibers. These observations appear to apply regardless of the orientation of the plies used to make up the panel.

The column chart, Figure 12, (titled WHWSWT Examples) shows specific examples of the shear strengths of the rods made from 33 different panels and the shear strength of the pins subsequently fabricated from these rods. All the panels in the chart were made using PEEK with carbon

reinforcing fibers, except the last panel which was made using PEEK with quartz reinforcing fiber. It may be seen that the pins made from each panel were 1 to 18 ksi lower in shear strength than the rods in each case with two exceptions. In the two cases where pin shear equaled rod shear, one instance is believed to be due to poor panel processing and the other to a fortuitous choice of samples.

As a result of these observations, the inventors devised a method of warm forming the head and threads of the fastener while maintaining a major portion of the shank at a temperature well below the melting point of the binder. This procedure ensured that no cross-sectional redistribution of the fibers would take place, formation of binder-rich areas would be avoided, and no significant departure from fiber straightness would occur in the shank portion.

The column chart, Figure 13, (titled <u>WHCSWT Examples</u>) shows specific examples of the ksi shear strengths of rods made from 10 different panels and the ksi shear strength of shear pins subsequently made from these rods using the process of the present invention. It may be seen that the shear strength of the pins is equal to the shear strength of the rods in four cases and is only 2 to 4 ksi lower than the rod shear strength in the remaining six cases. It may be seen that, in general, the pins made by the new process retain a markably higher percentage of the shear value of the original rods than the pins made by the old art WHWSWT process.

A schematic drawing of the fastener 10 made by the method of the invention is depicted in Figure 6. The fibers 30 in the head 12 and tail 16 portions are shown formed into patterns which provide good resistance to head collapse under tension loads and good resistance to thread stripping also under tension loads. By way of contrast, the fibers 30 in the shank portion 14 are shown as straight, illustrating the uniform distribution of the fibers throughout the cross-section, the lack of binder-

rich regions throughout the cross-section, and the straightness of the fibers. This is the desired fiber configuration for maximum shear strength.

A further advantage to the method of the present invention is that the panel can be fabricated in a panel press according to the optimum conditions of temperature and pressure which will result in the optimum condition of crystallinity and fiber "wet out" that will in turn give maximum shear strength properties in the rods. Rate of temperature rise, time at heat and time to cool can be accurately controlled and coordinated independently by a computer. Because the shank portion of each rod remains cool in the subsequent warm forming operation, the ideal "as pressed" structure is maintained. By contrast, in the old art of warm forming, all of the rod including the shank portion, is heated to about the same temperature as that used in the panel press but heating and cooling rates, dwell time at temperature and pressure applied during each stage are difficult to control accurately. Furthermore, the warm forming operation during which a rod is formed into a pin takes place in a few minutes, while the panel making process, using controls on pressure time and temperature for optimum shear strength, requires typically one hour. Thus the condition of the shank is unlikely to be such as to provide optimum shear strength.

A device for producing the fastener of the present invention is shown in Figures 7-9. Referring to Figure 7, the blank 52 with its head end 54, shank portion 56 and tail end 58 is placed into a series of dies, the shank die 100, head die 102, upset die 104, and thread die 120. The shank die 100 surrounds the fastener shank portion 56 and provides support thereto throughout the forming process. An additional purpose of the shank die 100 is to keep the shank portion of the fastener below the melting point of the binder, 650°F in the case of PEEK. To accomplish this end, the shank die may be conveniently formed of a ceramic

or other insulative material which limits the conduction of heat into the shank from the remainder of the tooling.

Directly above the shank die 100 is the head die 102. Directly above the head die 102 is the upset die 104. The upset die 104 is heated by means of the electrical resistance head heating coil 112 disposed therearound. Of course, one of ordinary skill in the art will recognize that the head end 54 of the blank 52 may be heated by means other than an electrical resistance coil.

Directly above the upset die 104 is the upper insulator 110, which may be conveniently made of ceramic or other insulative material. The purpose of this upper insulator is to reduce conduction of heat upward from the upset die 104 into the remainder of the tooling. The upper insulator 110 may be received by an upper jig 114 or any suitable retaining member. Slidably disposed within upset die 104 is head upset pin 106. This pin is urged against the blank head end 54 by the upper ram 116.

Directly beneath the shank die 100 is the thread die 120. Disposed around the thread die 120 is the electrical resistance tail heating coil 130. As with the head heating coil 112, one of ordinary skill in the art will recognize that there are additional equivalent means by which the blank tail end 58 may be heated.

Slidably disposed within the thread die 120 is the thread upset pin 122. Thread upset pin 122 is urged against the blank tail end 58 by lower ram 132. Heat from the thread die 120 is contained therein by lower insulator 124, which may be supported by lower jig 126 or any other suitable means.

Referring to Figure 7, the blank 52 is shown placed in the tooling ready for application of heat and pressure to form the threads and head. Referring to Figure 8, a threaded rod 60 is shown, after the lower ram 132 has urged the blank tail end 58 upward so as to deform the blank tail end 58 into the thread forming cavity 134. Accordingly,

threads 20 have been formed on the blank 58 to form threaded blank 60.

Throughout the above-mentioned operation, upper ram 116 and head upset pin 106 have remained stationary. Because the head heating coil 112 has not been energized, and no heat has been applied to the blank head end 54, the head end 54 has undergone no appreciable deformation. Upon formation of the threads, the tail heating coil 130 is deenergized and allowed to cool. Next, the head heating coil 112 is energized and the upset die and blank head end 54 are heated. Once the blank head end 54 is heated to the forming temperature of approximately 725°F, the head upset pin 106 is urged forcibly against the blank head end 54 by the upper ram 116. The compression urges the material of the head end 54 to deform and fill the head cavity 108, thereby forming the fastener head 12 as shown in Figure 9. The head heating coil 112 is then deenergized and allowed to cool.

Once the entire blank has cooled well below the melting point of the binder, 650°F in the case of PEEK, to about 400°F, the various sections of the tooling may be dismantled and the completed fastener 10 may be removed from the die. Some trimming of the head 12 may be required to remove flash and excess material in order to achieve the precise head dimensions required.

The invention has been described in the context of certain preferred embodiments, but these are examples only and the scope of the present invention is not restricted thereto. It will be easily understood by those skilled in the art that other variations and modifications can be easily made within the scope of this invention. For example, one of ordinary skill in the art will appreciate that the head and tail portions of the fastener may be formed in either order, head-first or tail-first. Likewise, it will be readily apparent that they might be formed simultaneously in some circumstances.

IN THE CLAIMS:

1. A fastener made of composite material including a plurality of fibers bonded together by a binder, said fastener comprising:

a shank wherein said fibers are generally straight; and

an end integral with said shank, wherein said fibers are not straight, having been deformed by heat and pressure during an end forming operation.

2. A fastener made of composite material including a plurality of fibers bonded together by a binder, said fastener comprising:

a shank wherein said fibers are generally straight; and

a warm formed head integral with said shank, wherein said fibers are not straight, having been deformed during a head forming operation.

3. The fastener of Claim 2, further comprising a warm formed tail integral with said shank opposite said head, said tail having threads formed therearound wherein said fibers are not straight, having been deformed during a thread forming operation.

4. The fastener of Claim 2, wherein said shank fibers are formed in plies in which the fibers are generally parallel to each other.

5. The fastener of Claim 4, wherein said plies are oriented so that the shank fibers are generally parallel to each other.

6. The fastener of Claim 5, wherein said plies are oriented so that the shank fibers are generally parallel to the longitudinal axis of said fastener.

7. The fastener of Claim 4, wherein a portion of said plies are oriented so that the shank fibers are not parallel to the longitudinal axis of said fastener.

8. A lightweight, high shear strength fastener made of composite material formed as a stack of plies, said plies

having a plurality of fibers oriented parallel to each other and bonded together by resin, comprising:

a generally cylindrical shank for bearing a shear load wherein said fibers are generally straight;

a head integral with said shank wherein said fibers are not straight, having been deformed by heat and pressure during a head forming operation; and

a tail integral with said shank opposite said head having external threads formed therearound wherein said fibers are not straight, having been deformed by heat and pressure during a thread forming operation.

9. A fastener made of composite material including a plurality of fibers bonded together by a binder, said fastener comprising:

a shank wherein said fibers are generally straight; and

a warm formed tail integral with said shank having threads formed therearound, wherein said fibers are not straight, having been deformed during a tail forming operation.

10. A method of making a fastener, comprising:

forming a fastener blank of composite material having a head end, a tail end, and a cylindrical shank interposed therebetween having a plurality of straight fibers extending generally parallel to the axis of said shank;

placing said blank in a die having a head forming cavity surrounding said blank head end;

heating said blank head end adjacent said head forming cavity to a temperature sufficient to permit deformation of said head end composite material while maintaining said blank shank below said temperature; and

compressing said blank axially so as to force heated blank head end material to deform into said head forming cavity to form a fastener head on said

head end, while maintaining said shank below said temperature so that the shank remains cylindrical and said shank fibers remain straight.

11. The method of Claim 10, further comprising:

placing said blank in a die having a thread forming cavity surrounding said blank tail end;

heating said blank tail end adjacent said thread forming cavity to a temperature sufficient to permit deformation of said tail end composite material while maintaining said blank shank portion below said temperature; and

compressing said blank axially so as to force blank tail end material to deform into said thread forming cavity to form threads on said tail end, while maintaining said shank below said temperature so that the shank remains cylindrical and the shank fibers remain straight.

12. The method of Claim 11, including insulating said shank during said heating and compressing steps to maintain said shank below said temperature.

13. The method of Claim 10, wherein said composite material comprises plies in which the fibers are bonded together by a binder and said temperature is the melting point of the binder.

14. A method of making an economical, lightweight, high shear strength fastener from a composite material formed as a unidirectional tape having a plurality of generally parallel fibers bonded together by a binder, said fastener having a generally cylindrical shank for bearing a shear load wherein said fibers are generally straight, a head integral with said shank wherein said fibers are not straight, having been deformed by heat and pressure during a head forming operation, and a tail integral with said shank opposite said head having external threads formed therearound wherein said fibers are not straight, having been deformed by heat and pressure during a thread forming operation, comprising:

stacking a plurality of plies of said tape;

heating and compressing said stack until said binder in said tape melts and bonds the adjacent plies so as to form a panel;

cutting from the panel a bar having a generally rectangular square cross section and having a longitudinal axis;

machining said bar into a generally cylindrical rod;

cutting said rod into a blank having a head end, a tail end, and a shank portion interposed therebetween;

placing said blank in a die having a thread forming cavity surrounding said blank tail end;

heating said blank tail end to a temperature sufficient to permit deformation of the composite material under pressure, while maintaining said blank shank portion below said temperature;

compressing said blank axially, so as to force blank tail end material to deform into said thread forming cavity to form threads on said tail end, while maintaining said shank below said temperature;

placing said blank in a die having a head forming cavity surrounding said blank head end;

heating said blank head end to a temperature sufficient to permit deformation of the composite material while maintaining said blank shank portion below said temperature; and

compressing said blank axially so as to force said blank head end material to deform into said head forming cavity to form a fastener head on said head end, while maintaining said shank below said temperature.

15. The method of Claim 14, wherein said stacking step comprises orienting the plies so that the fibers are substantially parallel to each other.

16. The method of Claim 15, wherein said plies are oriented so that the fibers are generally parallel to the longitudinal axis of said fastener.

17. The method of Claim 14, wherein said stacking step comprises orienting a portion of said plies so that the fibers are not parallel to the longitudinal axis of said fastener.

18. A fastener made by the method of Claim 10.

19. A fastener made by the method of Claim 11.

20. A fastener made by the method of Claim 14.

21. A method of making a fastener comprising:

forming a blank of composite material having a generally cylindrical shank for bearing a shear load, a head integral with said shank, and a tail integral with said shank opposite said head;

placing said blank in a die having a thread forming cavity surrounding said blank tail, a head forming cavity surrounding said blank head;

selectively heating said blank tail adjacent said thread forming cavity to a temperature sufficient to permit deformation of said tail composite material while maintaining said blank shank below said temperature;

compressing said blank tail so as to force blank tail material to deform into said thread forming cavity to form threads on said tail;

selectively heating said blank head adjacent said head forming cavity to a temperature sufficient to permit deformation of said blank head while maintaining said blank shank below said temperature; and

compressing said blank so as to force blank head material to deform into said head forming cavity to form a fastener head on said blank head.

22. An apparatus for forming a high shear strength fastener from a blank of composite material having a plurality of fibers bonded together by a binder, said blank

having a head end, a tail end and a shank portion interposed therebetween, comprising:

a head die for forming the fastener head;

a thread die for forming the fastener threaded portion;

head heating means for heating the blank head end within said head die above the melting temperature of said binder;

tail heating means for heating the blank tail end within the thread die above the melting temperature of said binder;

head upset means for urging the blank head end material into the head die so as to form a fastener head;

tail upset means for urging the blank tail end material into the thread die so as to form a fastener threaded portion; and

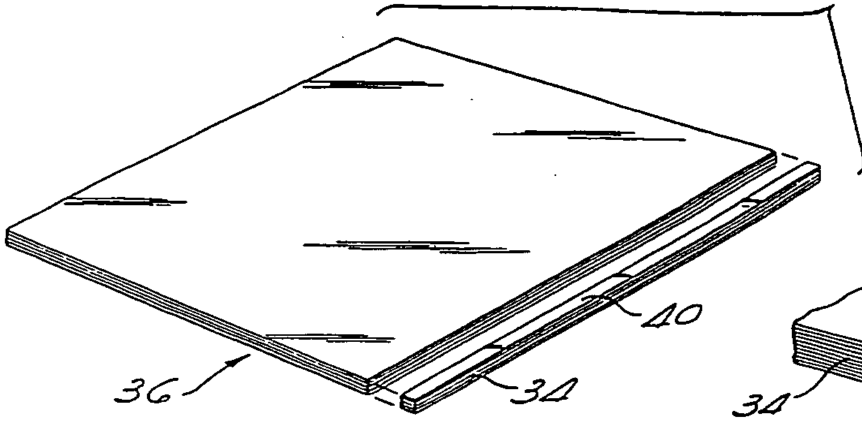
insulating means for keeping the blank shank portion below the melting temperature of said binder so as to keep the fibers therein generally straight and uniformly distributed and to prevent the formation of binder-rich areas therein, thereby maintaining the shear strength of the fastener shank.

23. The method of Claim 11, wherein said thread forming cavity creates a thread having an outer diameter which is no greater than the outer diameter of said shank, and said method including the step of reducing the diameter of said blank tail to be smaller than the interior diameter of said thread forming cavity.

24. The method of Claim 14, including the step of machining said blank tail end to a cylindrical shape having an outer diameter smaller than the interior diameter of said thread forming cavity, and wherein said thread forming cavity has an outer diameter no greater than the outer diameter of said blank shank portion so that the thread formed on said blank tail end has an outer diameter no greater than said blank shank portion outer diameter.

25. The method of Claim 21, including the step of machining said blank tail to a cylindrical shape having a diameter which is less than the inner diameter of said thread forming cavity, and wherein said thread forming cavity is dimensioned to create a thread on said blank tail which has an outer diameter no greater than the outer diameter of said blank shank.

Fig. 1



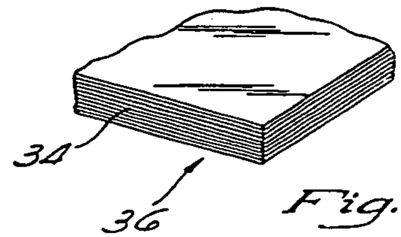


Fig. 2

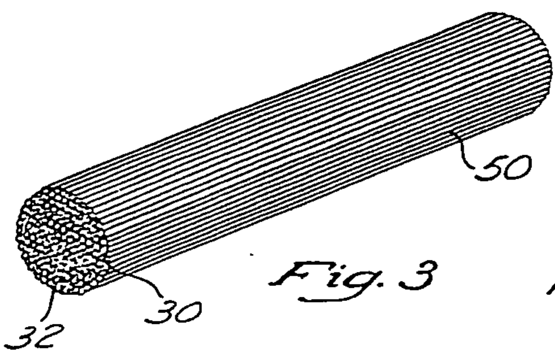


Fig. 3

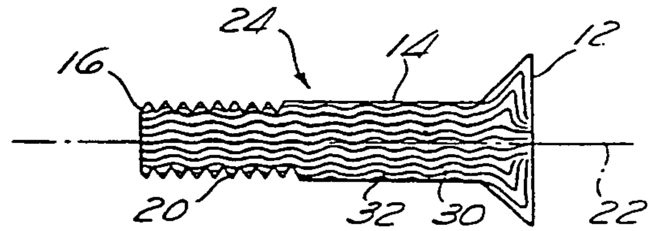


Fig. 5
(PRIOR ART)

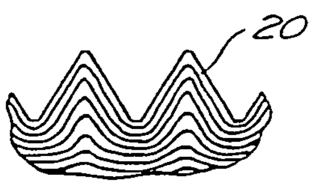


Fig. 10

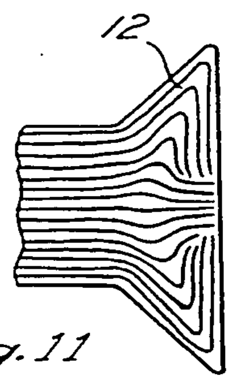


Fig. 11

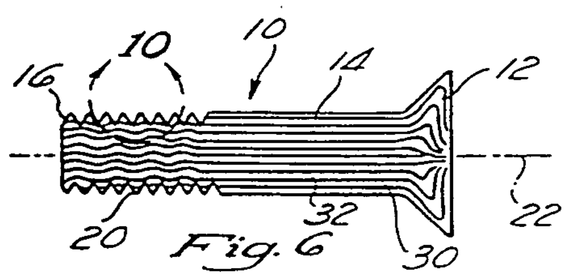
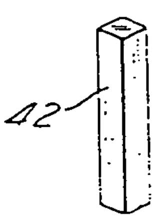
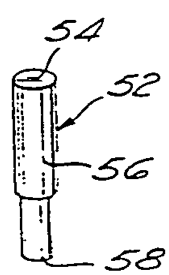
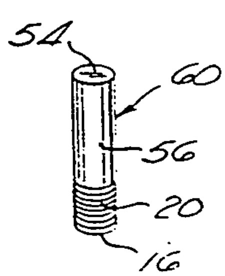


Fig. 6







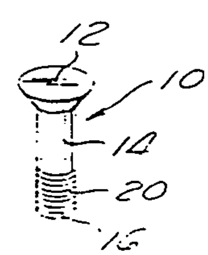


Fig. 4a Fig. 4b Fig. 4c Fig. 4d

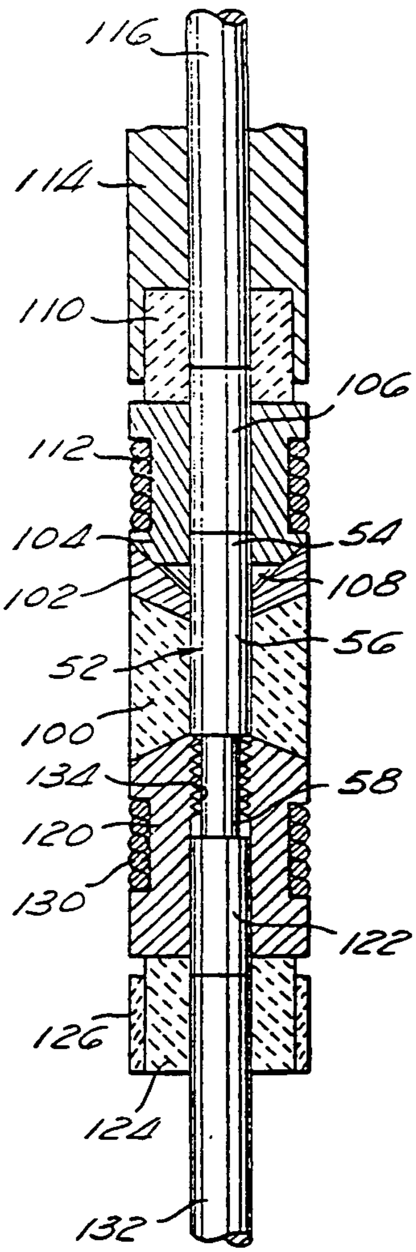


Fig. 7

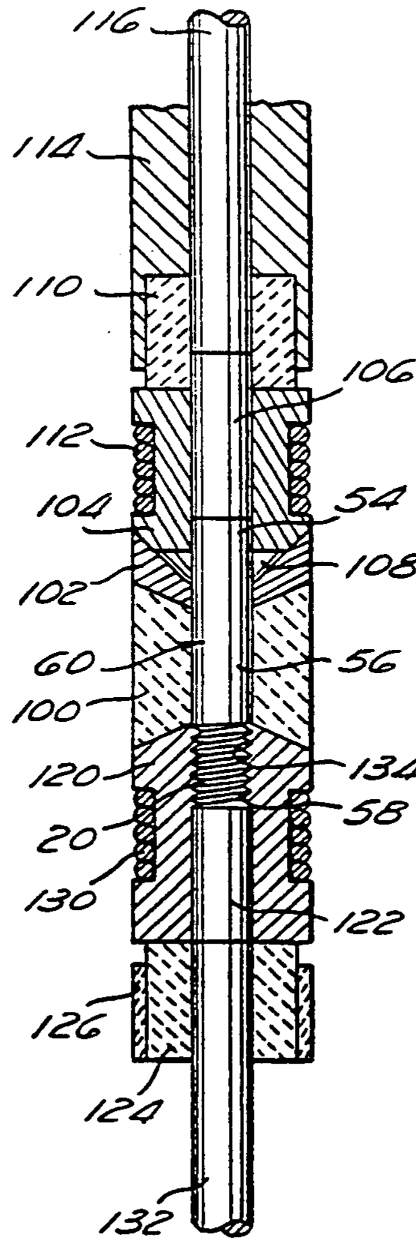


Fig. 8

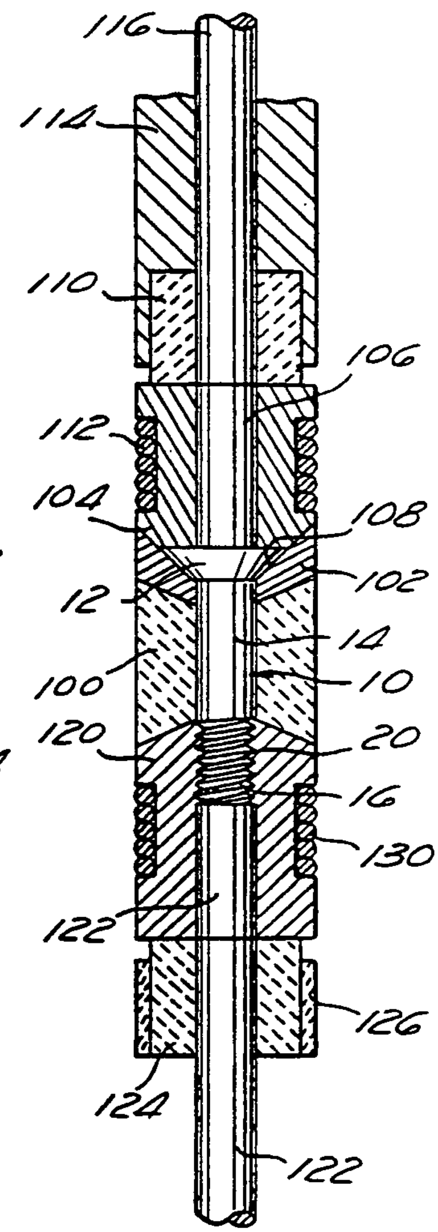
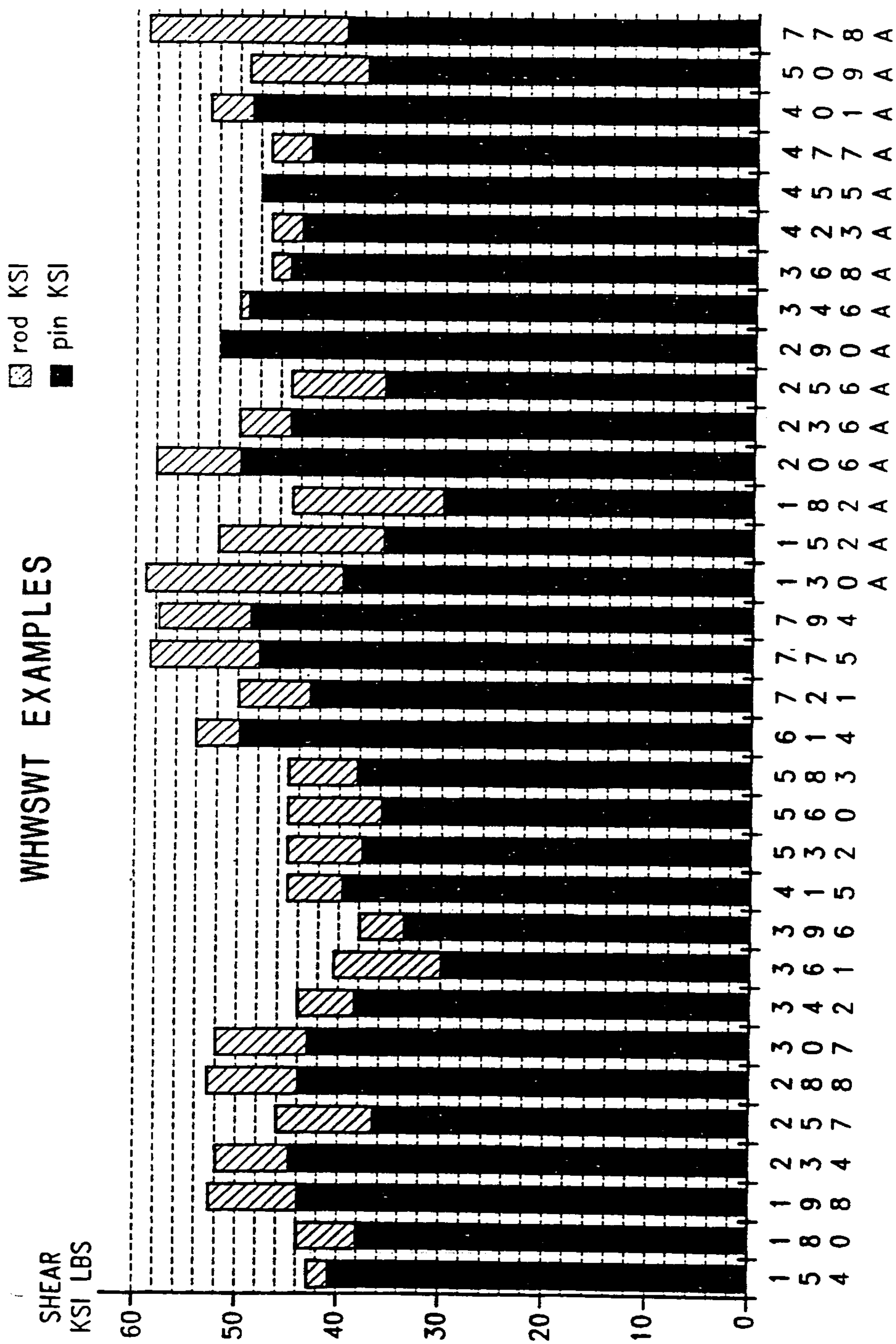


Fig. 9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pin KSI
SHEAR KSI LBS
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361
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415
532
560
583
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721
775
794
130A
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423A
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401A
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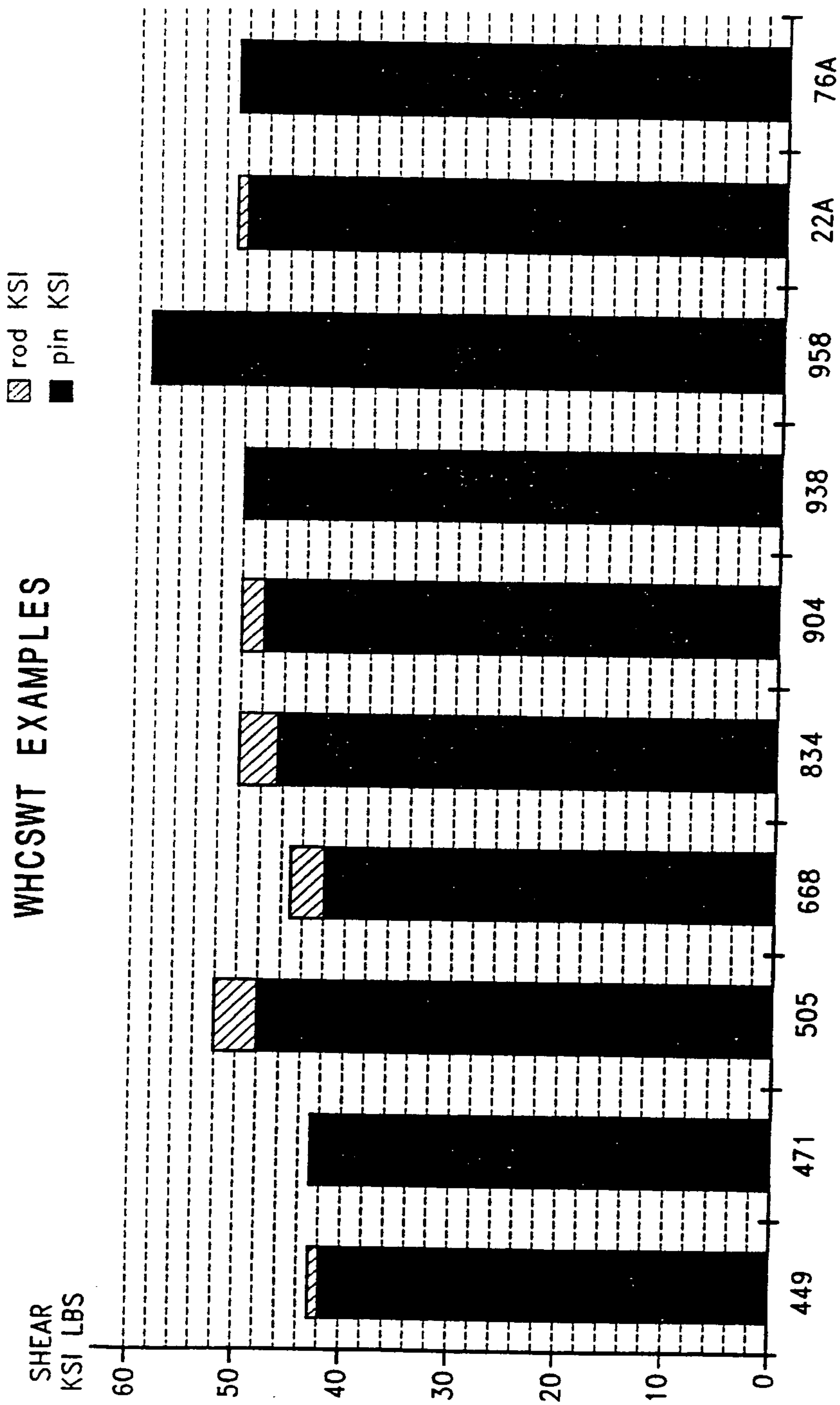
778A

FIG. 12


WHCSWT EXAMPLES
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KSI LBS
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668
834
904
938
958
22A
76A

FIG. 13

INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/04803

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC
INT. CL(5) F16B 35/00; B21H 3/02; B29B 7/00; B22D 27/02; B28B 7/42
U.S.CL. 411/411,424; 10/10R,27R; 264/322,327; 249/78

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	411/411,424,361,900-903,908; 10/2,10R,27R,27H; 264/310,318,320,322,327,328.16; 249/78-81

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X P	US, A, 4,863,330 (OLEZ ET AL) 05 September 1989	1-3,9-12,18,19,21-23
A	US, A, 2,949,054 (WHITE) 16 August 1960	
A	US, A, 2,901 455 (JURRAS) 25 August 1959	
A	US, A, 4,473,738 (WOLFE ET AL) 25 September 1984	
A	US, A, 4,362,042 (CROW, JR.) 07 December 1982	
A	BRITIAN, 1,364,076 (EVANS) 21 August 1974	
A	BRITIAN, 1,155,708 (HEIMANN) 18 June 1969	

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
07 NOVEMBER 1990	28 DEC 1990
International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	Veronica Ewell for NEILL WILSON